ON THE MANGROVE AND SALTMARSH VEGETATION NEAR SYDNEY, NEW SOUTH WALES, WITH SPECIAL REFERENCE TO CABBAGE TREE CREEK, PORT HACKING.

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(With Plates xxvi.-xxxii.; and eleven Text-figures.)

The observations recorded in the following paper were commenced during September (Spring) 1916 and continued with some interruptions until June. 1921.

It is the aim of the writer to give an account of the nature of the tidal flats and their vegetation, in the neighbourhood of Sydney, and more especially, to describe a series of changes which have taken place, during the past five years, at Cabbage Tree Creek, Port Hacking.

The writer's thanks are due to Professor T. G. B. Osborn, University of Adelaide, for much helpful discussion throughout the course of the work, and to Mr. J. H. Maiden, F.R.S., Director of the Botanic Gardens, Sydney, who kindly gave her access to the National Herbarium. To Mr. A. A. Hamilton, the writer is indebted for assistance in identification of the various species collected.

Physiographic Features of the Coast near Sydney.

The coastal strip in the neighbourhood of Sydney shows many features of marked physiographic interest. It is characterised by striking, much branched inlets, in which, for the most part, deep water is found close up to the rocky shores. Woolnough says of these ". . . . they owe their existence to the submergence of a partially dissected plateau"; also, "At the close of the latest cycle of erosion there was a general subsidence amounting to at least 400 feet in the central portion of the area. [referring to the coast of New South Wales.] This caused the 'drowning' of the valleys of the coastal rivers, and the conversion of these drowned valleys into magnificent harbours" (Jose, Taylor and Woolnough, 1911, p. 131).

Port Jackson, Botany Bay and Port Hacking, which come within the scope of the present work, all represent drowned river valleys with complex outline (Text-fig. 1). The rocks outcropping on the shores of these inlets, and

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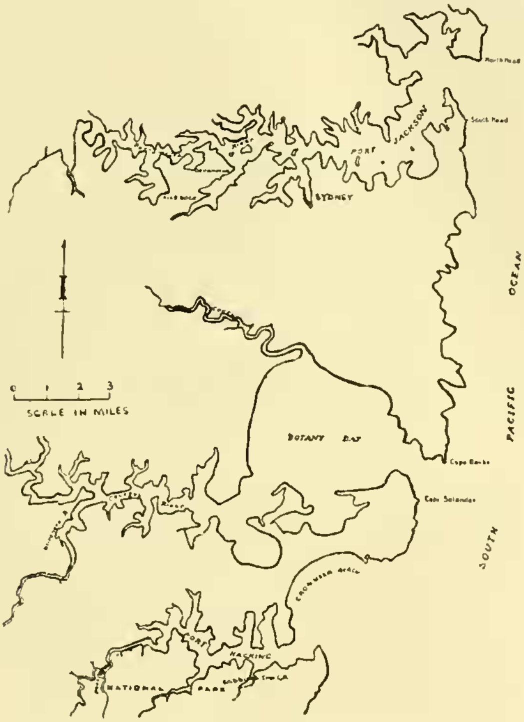
*This investigation was commenced in 1916 while the writer held a Science Research Scholarship in the University of Sydney.

for some distance inland, are chiefly Triassic sandstones of the Hawkesbury Series which yield upon denudation a coarse yellow sand.

Since no important rivers flow to the sea in this region, the so-called Parramatta and Lane Cove Rivers merely being arms of Port Jackson, and George's River (Botany Bay) and Port Hacking River (Port Hacking) being insignificant streams, silt and detritus are not carried out to sea, but tend to be deposited in sheltered arms and bays.



Text fig. 1. Map of coast of New South Wales between Port Jackson and Port Hacking showing the nature of the drowned river valleys, and the sheltered arms and bays in which mangrove and saltmarsh occur.

That there has been comparatively recent subsidence on the coast near Sydney is evidenced in the fact that a bore sunk in the mud at Narrabeen lagoon (north of Port Jackson) disclosed at a depth of over 50 feet layers of Peaty soil containing *Casuarina* cones, and remains of other Xerophytes which now occupy the sandstone country surrounding the lagoon (David and Halligan, 1908, p. 235).

This recent subsidence, together with the physiographic features mentioned above, possibly accounts for the non-existence of such extensive areas of tidal flats as are found in other parts of the world (Ganong, 1903; Harshberger, 1909; Carey and Oliver, 1918); unless the accumulation of silt were sufficiently rapid to keep pace with and overcome the effects of gradual subsidence, the formation of mud flats and their colonisation by plant and animal life, would necessarily be postponed until a condition of equilibrium had been attained. Once the bank of muddy silt is raised above low tide level, seedlings of *Avicennia officinalis* Linn. (Australian Grey Mangrove) establish themselves, and aid in the building up of a mud flat. The mud is generally black and of a coarse, sandy nature, punctured at frequent intervals by crab-holes (*see* Hedley, 1915, p. 46) and becoming foetid from the decay of various Algae, shellfish and drift material. These play an important part in providing humus and in aiding the building up of the flats.

THE VEGETATION OF THE TIDAL FLATS.

The tidal lands which come within the scope of the present paper are to be found chiefly in the upper reaches of the Iron Cove, Parramatta River, Lane Cove River, and Middle Harbour—all arms of Port Jackson; along the banks of Cook's and George's Rivers flowing into Botany Bay, and in the sheltered arms of Port Hacking. The area ranges from 33° 50' to 34° 5', S. Lat. and extends from Port Jackson south of Sydney for a distance of about sixteen miles (Text-fig. 1).

The area in Port Hacking to which the writer has given special attention is that of Cabbage Tree Creek, where an interesting series of changes is taking place, owing to the raising of the level of the saltmarsh by wind-blown sand.

Previous Investigations.

Extra-tropical mangrove and saltmarsh vegetation in Australia has been dealt with by but few writers. In his description of tidal woodland, Schimper (1903, p. 409) records the occurrence of the mangroves *Avicennia officinalis* Linn. (*Verbenaceae*) and *Aegiceras majus* Gaertn. (*Myrsinaceae*) on the coast of New South Wales. This record is briefly descriptive and deals with the nature of the viviparous seedlings in the two genera (p. 400).

Hedley (1915, pp. 44-46) records the same species for Port Jackson and gives Wilson's Promontory in Victoria as the most southerly station in Australia for *Avicennia officinalis*.

In a preliminary account of the coastal vegetation near Adelaide, Osborn (1914, pp. 584-586) records *Avicennia officinalis* as the only mangrove present. This writer also refers to the presence of *Suaeda maritima** mingling with the mangrove on its shoreward side. *Salicornia* swamps (with *Salicornia australis* Soland. and *S. arbuscula* R. Br.†) which are only subjected to occasional tidal inundation, are found on the shoreward side of the mangrove. Zonation is recorded in these swamps, the zones being as follows: "(1) *Salicornia*; (2) *Salicornia* and *Samolus repens*; (3) *Samolus repens* and *Sporobolus virginicus*; (4) *Sporobolus, Spergularia*, etc."

Western Australian extra-tropical mangrove has been dealt with by Dr. C. H. Ostenfeld (1918, pp. 1-12). This writer recognises three shore line formations on the coast of Western Australia, south of the Tropic.

1. MANGROVE FORMATION.
2. SANDY SEA SHORE FORMATION.
3. SALT PAN FORMATION.

**See* reference to Paulsen below.

†Recent investigations by Black (1919) into South Australian *Salicornieae* point to the plant hitherto known as *Salicornia arbuscula* being in reality *Arthrocnemum arbuscula*.

Avicennia officinalis is recorded as being the only woody plant in Western Australian mangrove formation south of the Tropic.

Ostenfeld refers to the mingling of the succulent halopyte *Suaeda* with mangrove at its higher levels. Paulsen's work on Western Australian *Chenopodiaceae* points to this being a new species, viz., *Suaeda australis* (1918, p. 65). The absence of other plants amongst the mangrove is attributed to the great force of the tides which reach a velocity of ten to twelve knots in places (Ostenfeld, 1918, p. 8).

In the salt pan formation, Ostenfeld describes the plant covering as being chiefly cushion forming *Chenopodiaceae,* species of *Arthrocnemum,* also *Salicornia australis* and *Samolus junceus* R. Br., etc. (Ostenfeld, 1918, Pl. 1, 2.)

In a recent paper on saltmarsh vegetation in the Port Jackson district, N.S.W., Hamilton (1919, p. 470) refers to three plant formations in the local estuarine flora. These are:—

1. The TIDE-FLOODED ZONE, with *Avicennia officinalis* and *Salicornia australis* as dominants.
2. The DRY SALT PLAIN, with sparse vegetation and scattered detritus mounds.
3. The FLUVIAL ZONE, separated from the former by a band of *Casuarina glauca* Sieb. (the Swamp Oak), and marking the encroachment of fresh water conditions upon brackish and saline.

BOTANICAL FEATURES OF A TYPICAL TIDAL MARSH NEAR SYDNEY.

The vegetation of a typical tidal marsh in the neighbourhood of Sydney, is made up of two plant formations:—

1. An outer TIDAL WOODLAND or MANGROVE FORMATION. (Pl. xxvi., Photo 1).
2. An inner SALTMARSH FORMATION.

In mangrove formation, there can be recognised but one plant association, comprising *Avicennia officinalis* and *Aegiceras majus,* while in saltmarsh formation there are generally two distinct associations, the outer in which *Salicornia australis* and *Suaeda australis** are usually co-dominants, and an inner, which marks the landward boundary of the marsh, is an almost closed association of the rush *Juncus maritimus* Lam.

Pioneer Phase of a typical tidal Marsh.

In the pioneer phase, the typical tidal marshes around Sydney are colonised by viviparous seedlings of *Avicennia officinalis* drifted up by the tides. The seedlings are provided with a pair of large fleshy cotyledons, surmounting a short, blunt hypocotyl (Text-figs. 2-4). They establish themselves readily, or are bound down by mats of the Alga *Cladophora* until the first roots have made their appearance. *Avicennia* grows on the outermost limits of the formation. It reaches a height of from fifteen to thirty feet and presents a striking appearance owing to the varying angles at which the trunks are bent to the foreshore (Pl. xxvii., Photo 2) and to the countless asparagoid pneumatophores which project vertically out of the mud (Pl. xxvi., Photo 3). These pneumatophores spring from long horizontal roots which radiate from the base of the tree, and are to be found at no great depth below the surface of the mud (Text-fig. 5, and Pl. xxix., Photo 8). This horizontal growth of the root system of *Avicennia* helps to consolidate the mud and prepare it for later colonisers.

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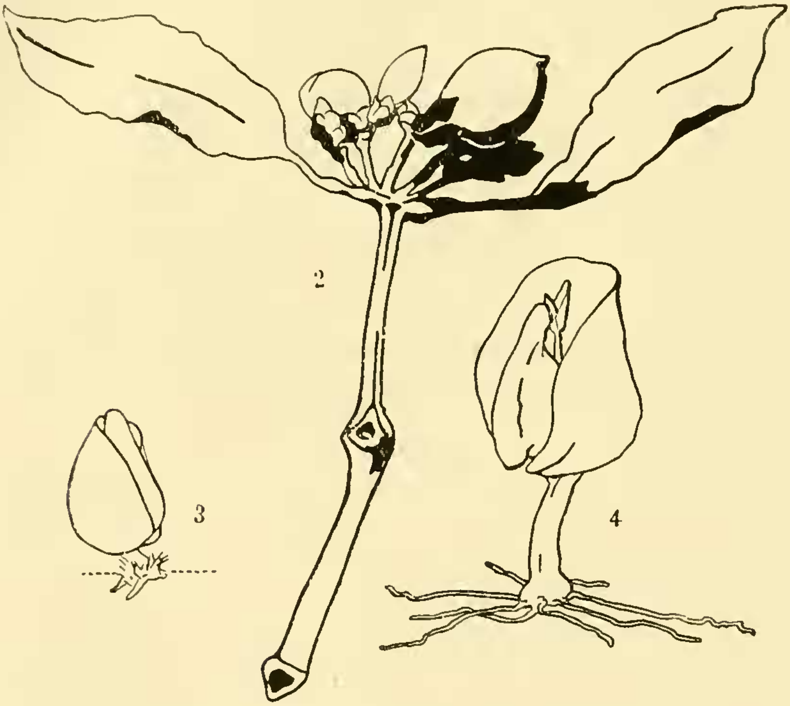
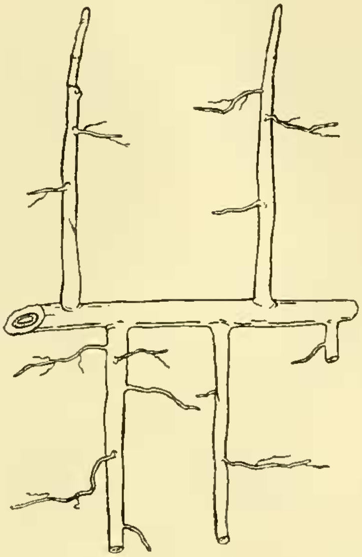
* Ove Paulsen's work on Chenopodiaceae (1918, pp. 55-66) indicates that the species of *Suaeda* in Australia hitherto known as *S. maritima* should be known as *S. australis* R.Br.



Text figs. 2-4. Viviparous seedlings of *Avicennia officinalis*.

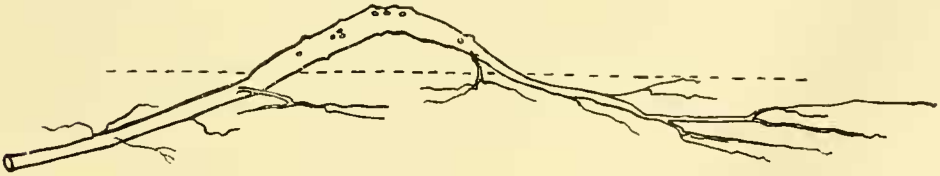
2. Attached to parent plant and still enclosed within pericarp. 3. After rupture of pericarp and showing establishment of seedling on mud; note circlet of hairs at base of hypocotyl and first roots projecting. 4. Later stage of establishment, where numerous roots have developed at base of hypocotyl and are taking up horizontal position on mud.

Aegiceras majus is by no means as constant a feature of mangrove formation near Sydney as is *Avicennia officinalis*. The former apparently reaches its southernmost limits on the coast of New South Wales, possibly at Cabbage Tree Creek, Port Hacking, to be described later. *Aegiceras* occupies the innermost limits of mangrove formation and is in striking contrast to *Avicennia officinalis* (Plate xxvii., Photo 4). It grows erect, and is, at most, a tall shrub (Pl. xxviii., Photo 5). Its average height near Sydney is about six feet. Its glossy green foliage stands out vividly against the grey-green of *Avicennia*, as do also its red, tannin-bearing branches against the ashy grey, lichen-coated trunks of *Avicennia*. The leaves of *Aegiceras majus* are remarkable in early morning for their coating of glistening salt crystals which are secreted by special complex glands (Solereder, 1908, 510). During the day, this fine layer of salt is swept away by on-shore breezes.



Text-fig 5. Pneumatophores of *Avicennia officinalis* showing relationship to the general root system.

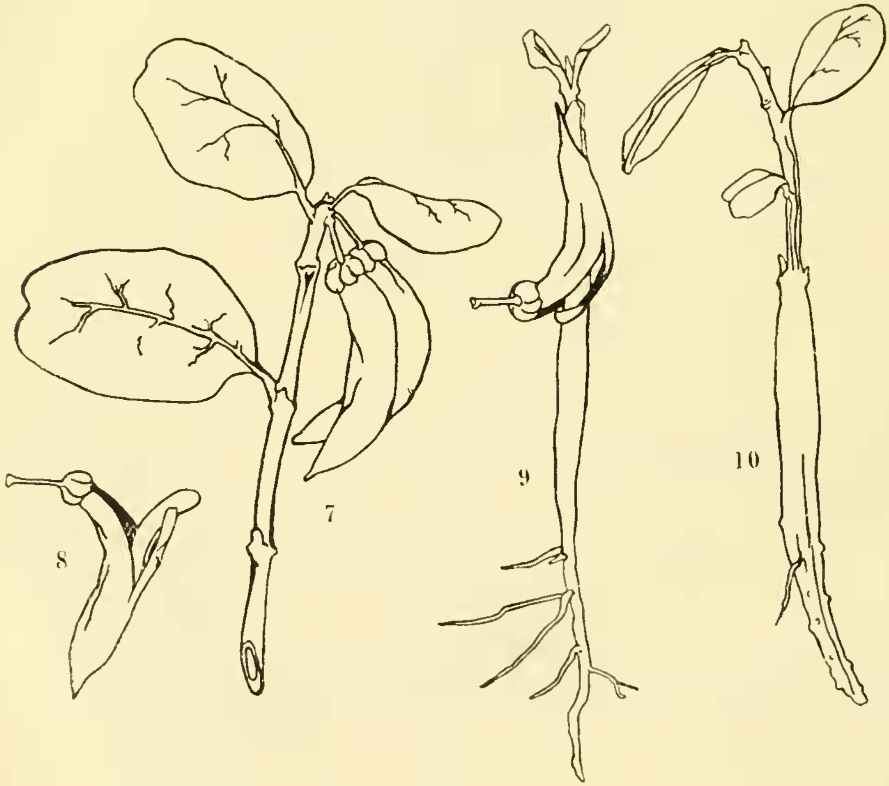
The root system of *Aegiceras* does not extend for such great distances from the plant as does that of *Avicennia*. The roots possess no special pneumatophores but occasionally run for a short distance over the surface of the mud, or rarely, are raised into knee-like projections (Text-fig. 6). In this *Aegiceras* more closely resembles certain tropical mangroves, e.g. *Bruguiera* (Schimper, 1903, p. 401). A special air-storing tissue is developed in the roots, connecting with large pneumathodes.



Text-fig. 6. Part of root system of *Aegiceras majus* showing knee-like projections above mud level.

Of the viviparous seedlings of *Aegiceras*, Schimper says (1903, p. 400) "The seedlings of *Aegiceras* are curved like horns, and are smaller than those of the *Rhizophoraceae;* they remain enclosed in the thin pericarp of the fruit." (*See* Pl. xxviii., Photo 6 of this paper).

The writer has observed various stages in the emergence and establishment of the young seedling of *Aegiceras*. The seedling drops to the mud, still enclosed within the thin brown pericarp of the fruit. It is not in such an advanced state as that of *Avicennia*. The hypocotyl is pronounced, green in colour and curved at the end from which the radicle is destined to develop. A pair of small green cotyledons are just discernible at the tip of the hypocotyl. After a time the pericarp splits and the curved portion of the hypocotyl elongates towards the mud (Text-figs. 7-9). The hypocotyl continues to grow and at length a thin colourless primary root penetrates the mud, from which secondary roots are given off later. In the meantime the pericarp has split again to allow the escape of the cotyledonary region and the plumule. The seedling becomes erect and the short epicotyl and first true leaves make their appearance the only trace of the original curvature of seedling being found where the root enters the mud. With the elongation of the seedling, the pericarp is carried some distance above the mud (Text-fig. 10), but after a time it decays and drops to the ground.



Text figs. 7-10. Various stages in the establishment of the viviparous seedling of *Aegiceras majus*.

The development of saltmarsh commences almost simultaneously with that of mangrove. Here *Salicornia australis* Soland. is the pioneer plant and often establishes itself to the exclusion of other species. In parts of the George's River and Botany Bay large areas are occupied by pure Salicornietum (Hedley, 1915, p. 46).

It is more generally found, however, that *Suaeda australis* follows *Salicornia* closely and becomes a co-dominant with the latter in the initial stages of Saltmarsh..

In order to understand the conditions which exist on the majority of tidal flats near Sydney, it is necessary to study the vegetation over a continuous period of time. It is only thus that developmental phases may be recognised and the true limits of the association established. The writer recognises two plant associations in salt marsh formation near Sydney:—

(i.) An outer mixed saltmarsh association corresponding to the "mixed salting" of British investigators (Carey and Oliver, 1918; Tansley, 1911). Since *Salicornia australis* is the dominant species here, the writer will refer to this association as *Salicornietum.*

(ii.) An inner almost pure association of *Juncus maritimus* which usually marks the boundary between the marsh and land flora—the *Juncetum.*

i. *Salicornietum.*

On young *Salicornia* association it is possible to recognise at least three developmental phases or associes in Clement's sense (1916, p. 136). These appear to be associated with slight differences in level and are present as zoned bands which show a certain amount of overlapping. The lowest of these, which abuts on the mangrove formation is the (*a*) *Salicornia-Suaeda* associes, characterised by *Salicornia australis* Soland. and *Suaeda australis* R. Br. These low succulent shrubs are inundated by all tides and together with the pneumatophores of *Avicennia officinalis* play an important part in the building up of the marsh by acting as retainers of silt. (*b*). At a slightly higher level is an associes in which *Salicornia* and *Spergularia rubra* are developed equally with a number of low spreading perennial halophytes. The plants of this associes arranged in order of dominance are:—(i.) *Salicornia australis* Soland. (ii.) *Spergularia rubra* Camb. (iii.) *Suaeda australis* R. Br. (iv.) *Samolus repens* R. Br. (v.) *Mesembryanthemum tegens* F. v. M. (vi.) *Tetragonia expansa* Murr. (vii.) *Atriplex patula* L. (Introduced) (viii.) *Wilsonia Backhousii* Hook.

(*c*). *Sporobolus-Cynodon* associes which occupies a marginal position within the association and is of sward-like physiognomy (Pl. xxviii., Photo 7). The chief constituents are *Sporobolus virginicus* Humb. and Kunth., *Cynodon dactylon* Rich. and *Zoysia pungens* Willd., but as there is no strong line of demarcation between these latter associes, particularly where the slope is gradual, there is often a profuse mingling of perennial halophytes with the above-mentioned grasses. That these are developmental phases of the mature *Salicornia* association is shown clearly in old saltmarshes, where the level has been raised by silt accretion and a fairly uniform surface prevails. Here a mixed association of annual and perennial halophytes is found occupying the whole area between the inner *Juncetum* and the outer mangrove formation. In this mixed meadow-like association. *Salicornia* and *Suaeda* are predominant on the outer margin, since here seedlings have a better chance of establishing themselves. Where bare patches are found in this association owing to destruction of underlying vegetation by decaying detritus, algal mats, and the like (Harshberger, 1916) the pioneer colonist *Salicornia* is not slow in making its appearance. Thus, in miniature, the history of the association repeats itself. The groups described above cannot be regarded as separate associations since they are all found mingling freely on old marshes where a fairly uniform surface level has been attained. Thus the term "Zonation" is not used in the same sense as by Yapp (1917, p. 68) in his description of the zoned vegetation of the marshes of the Dovey Estuary in Wales.

ii. *Juncetum Maritimi.*

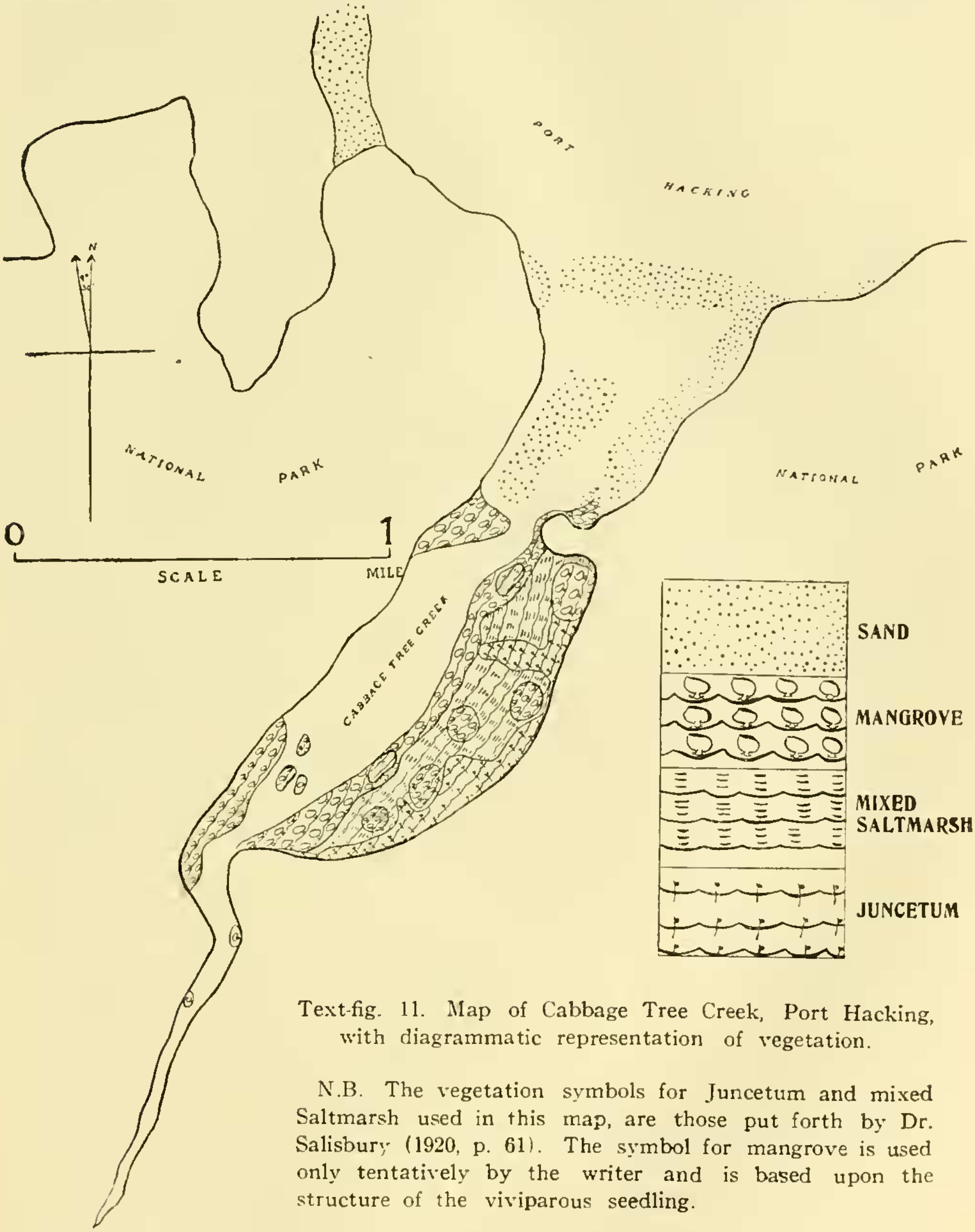
The inner association of Saltmarsh formation near Sydney is of interest since it generally marks the landward boundary. It is often a pure association of *Juncus maritimus* Lam., but as Hamilton has shown, further species of *Juncus* (1919, pp. 480-482) and *Cladium junceum* (1919, p. 480) are often found. An interesting feature of this association is the presence in it of the "swamp oak" *Casuarina glauca* Sieb. These trees are generally found lining the banks of the marsh on the extreme outer limits of the *Juncetum* but occasionally they occur in local patches of slightly higher level within the association (Pl. xxxi., Photo 13). From superficial observation it is apparent that in the saltmarshes around Sydney differences in level, and consequently in drainage, play a large part in the delimitation of the plant associations. This should not form the subject of any generalisation, however, until careful mud analyses have been made and the results compared for different localities.

CABBAGE TREE CREEK, PORT HACKING.

Cabbage Tree Creek is a small stream entering Port Hacking on its southern side, at a distance of about two miles from the sea. The shore between the mouth of the creek and Port Hacking Point is indented by narrow sandy beaches of varying length (*See* Text-fig. 1). In a north-easterly direction from the Creek is Cronulla Beach, backed by high mobile sand dunes which extend across to Botany Bay. The entrance to Cabbage Tree Creek is partly blocked at low tide by sand spits and shoals (Text-fig 11). The larger sand spit projects from the southern shore and resembles in miniature, the sand bars which form a characteristic feature of the lagoons such as Deewhy, Narrabeen, etc., north of Port Jackson (Jose, Taylor and Woolnough, 1911, p. 136).

The main body of the creek may be divided into two parts, the upper fresh-water to brackish region which runs between gradually ascending sandstone slopes, and a lower, wider, basin-like region in which the water is distinctly saline. The southern shore of this lower portion of the creek is markedly concave, and it is here that an extensive tidal marsh has developed. Storm waters entering the creek are sufficient to keep the central channel clear, but since the creek narrows when nearing the mouth, its load of silt and detritus tends to be deposited upon the concave southern shore.

When the writer first visited Cabbage Tree Creek in 1916, a short strip of sandy beach abutted on the southern side of the creek entrance. At the point where this sandy beach reached the outlying mangrove at the mouth of the creek, young plants of *Avicennia officinalis* Linn. and *Aegiceras majus* Gaertn. were already showing signs of burial in drift sand. On the beach itself were recognisable two distinct zones, the strand, with clumps of *Salsola Kali* Linn. a little above high tide level, and small transitory hummocks occupied by *Senecio lautus* Soland. The second zone, that of larger hummocks or embryonic dunes, was characterised by an association of such plants as *Mesembryanthemum aequilaterale* Haw., *Scaevola suaveolens* R. Br., *Senecio lautus* Soland., *Spinifex* *hirsutus* Labill., etc. Behind, the beach passed into stable or fixed dune region characterised by sclerophyllous scrub with *Acacia armata* R. Br., *Leucopogon richei* R. Br., etc. At the present day the beach shows a completely altered appearance. A few scattered seedlings of *Salsola Kali* are establishing themselves upon the strand, but all that remains of the mobile dune zone are the decaying trails of *Spinifex hirsutus*, exposed by the action of the wind. Areas



Text-fig. 11. Map of Cabbage Tree Creek, Port Hacking, with diagrammatic representation of vegetation.

N.B. The vegetation symbols for Juncetum and mixed Saltmarsh used in this map, are those put forth by Dr. Salisbury (1920, p. 61). The symbol for mangrove is used only tentatively by the writer and is based upon the structure of the viviparous seedling.

occupied by mats of *Scaevola suaveolens,* over 6 feet in diameter, have ceased to exist.

The alteration of the vegetation covering this beach, suggests that the piling up of sand against the mangrove at the entrance to Cabbage Tree Creek is due to the activity of southerly gales rather than to the continuous and milder action of the prevailing north-easterly winds. (*See* Jose, etc., 1911, p. 136). It is possible, however, that the north-easterly winds carry a load of sand from the dunes behind Cronulla Beach and that a certain amount of this finds its way to the marshes at Cabbage Tree Creek.

The chief points of interest at Cabbage Tree Creek, at the present day, are the raising of the level of the tidal marsh by drift sand deposited on the surface of the mud, and the gradual blocking of the creek entrance by sand spits and shoals. The effect of both these changes is to lessen the amount of tidal inundation and to bring about alteration in the physical properties of the soil.

At the present day the tidal marsh at Cabbage Tree Creek presents a complex problem for solution. There does not appear to be any marked definition between mangrove and saltmarsh formations, and within the saltmarsh it is difficult to define the boundaries of the plant associations.

As on the marshes near Sydney, the outermost formation at Cabbage Tree Creek is mangrove in which *Avicennia officinalis* and *Aegiceras majus* are the only species. At the entrance to the Creek *Avicennia* and *Aegiceras* are being buried in drift sand (Pl. xxix., Photo 9). The area between the low tide level and the shore is occupied by saltmarsh which shows some striking differences from saltmarsh at Port Jackson. An interesting feature is the occurrence, throughout the saltmarsh, of groups of *Avicennia officinalis.* The innermost of these are only reached by the highest tides and may be regarded as being stranded. Their position in isolated areas within a newer formation is comparable with certain geological formations known as "inliers." These mangrove "inliers" indicate that rise in level of the mud surface has brought about the imposing of saltmarsh flora upon what was once entirely mangrove (Text-fig. 11 and Pl. xxxii., Photo 10).

Extensive areas at Cabbage Tree Creek are populated by dwarf Avicennia, (Pl. xxx., Photo 12) in which the main trunk is shortened and averages about one foot in height. The lateral branches are given off from this stocky trunk and take up a position parallel to the ground (Pl. xxx., Photo 11). Hamilton (1919, p. 470) records dwarf *Avicennia* at Homebush Bay, on the Parramatta River, and attributes their diminished form to dilution of tidal waters by fresh water from the inland drainage channels.

Warming (1909, p. 25) refers to the effect of temperature and the length of the vegetative season upon the external morphology of plants. He points out that dwarf forms occur when the vegetative season is short and the temperature low, as in arctic regions, or where high temperatures are combined with low water supply. Until a special investigation has been made of soil and temperature relations, the writer is not in a position to offer any reason for the occurrence near Sydney of localised areas of dwarf-*Avicennia.* It is sufficient for the present to say that the writer regards this as a definite growth-form and in no way comparable with the general lowering of stature observed in mangroves as they occur farther from the tropics (Schimper, 1903, p. 409).

In 1916 the saltmarsh at Cabbage Tree Creek, Port Hacking, had passed through its pioneer phase, *Salicornia australis* and *Suaeda australis* being in full occupation of the mud immediately behind the mangrove, and in places penetrating through the mangrove to low water level. Other halophytes, such as *Samolus repens* and *Spergularia rubra* had begun to spread over locally elevated patches.

At the present day there are but few species represented on this saltmarsh in comparison with the marshes of Port Jackson and George's River.

The plants recorded are:—

1. Salicornietum.
   - *Salicornia australis.*
   - *Samolus repens.*
   - *Sporobolus virginicus.*
   - *Suaeda australis.* (few isolated plants).
   - *Spergularia rubra.* (few isolated plants).
2. Juncetum.
   - *Juncus maritimus,* with occasional patches of *Casuarina glauca.*

Juncus maritimus does not occupy the landward fringe only, but shows encroachment upon the Salicornietum. Bands of *Juncus* have traversed the saltmarsh to the outer fringe of mangrove in places (Text-fig. 11; also Pl. xxxi., Photo 14).

It is in this invasion by *Juncus* of Salicornietum perhaps, that we can partly account for the paucity of species in the latter. It seems likely that the rate of raising of the level of the marsh is greater than that of establishment of species. The remarkable diminution in number of plants of *Suaeda australis* is doubtless owing to unfavourable conditions for establishment of seedlings. Also the formation of extensive meadow-like areas of *Samolus repens* (Pl. xxx., Photo 11) within the Salicornietum, is apparently helping to make conditions unfavourable for the establishment of other species on account of its close mat-like growth.

In this marsh there has been a hurrying over certain developmental phases, so that it is impossible to recognise any transitory groupings or associes within the associations.

Thus, in certain important features, the tidal marsh at Cabbage Tree Creek differs from the typical marshes of Port Jackson and Botany Bay. Here, owing to special conditions, one plant formation has been imposed upon another, and, within the second formation, one association (Juncetum) has invaded and arrested the development of the other (Salicornietum).

General Discussion.

The subsidence of a coastal region of youthful topography and the subsequent drowning of river valleys, has been, in part, responsible for the comparatively restricted nature of the tidal marshes in the neighbourhood of Sydney. The absence of any large, delta-forming rivers, has resulted in the limitation of saltmarsh to the silted bays and creeks found in the arms of drowned river valleys such as Port Jackson, Botany Bay and Port Hacking. These stations are always sheltered from the open sea and consequently the part played by certain Algae in their consolidation is not so important as is the case in certain British saltmarshes (Carey and Oliver, 1918, p. 170). Although the writer has made no attempt to deal with the algal vegetation of the saltmarshes near Sydney, it might not be out of place to record the occurrence of species of *Cladophora, Ulva* and *Enteromorpha,* the first of which is apparently not represented on the British saltmarshes (Carey and Oliver, 1918, p. 267). Leaves of the grass-wrack *Zostera,* washed up by tides, probably play a more important part in New South Wales in helping to consolidate and in adding organic matter to the mud. In the pioneer phases, saltmarsh near Sydney resembles

British and Eastern American marshes only in so far as some species of *Salicornia* is the first coloniser and is followed closely by *Suaeda*.

The British (Carey and Oliver, Howarth, Newman and Walworth, Yapp, etc.), Danish (Warming), French (Hill, Oliver) and American marshes (Ganong, Harshberger, Johnson and York) are characterised by the extensive development of grasses which enter into competition with other halophytes at an early stage. In certain Welsh marshes, *e.g.* on the Dovey Flats, the grass *Glyceria maritima* often replaces *Salicornia* as the pioneer coloniser. *Glyceria maritima* together with the grasses *Festuca rubra*, *Lepturus filiformis*, and *Agrostis alba*, and certain shrubby perennial halophytes, forms a compact turf which becomes of economic value for grazing (Yapp, etc., 1917, p. 72). On the American marshes the tall grass *Spartina glabra* (*stricta*) occupies the outermost fringe of the mud (Ganong, 1903. Johnson and York, 1915). In the marshes near Sydney, grasses do not play so important a part. They do not appear until a late stage in development and then are often represented by only one species—*Sporobolus virginicus*. Other grasses do occur with *Sporobolus*, however, the most important being *Zoysia pungens* and *Cynodon dactylon*. Hamilton records the occurrence of species of *Lepturus* and *Calamagrostis* (1919, p. 485) but does not make it clear as to whether these are to be regarded as true saltmarsh grasses.

The grass *Festuca rubra* appears to be a consistent feature of the British saltmarshes (Howarth, 1920; Newman and Walworth, 1919). From a comparative table given by Howarth to show zonation of vegetation on various British marshes, it is seen that while *Festuca rubra* or one of its sub-varieties is always present, its position in relation to the plant associations of the marsh varies for different localities. It is either entirely inside the limits of Juncetum, forming an association of its own, *e.g.* the Festucetum of the Dovey Flats (Yapp, etc., 1917, pp. 69-70) or it occurs as a co-dominant with *Juncus* at Holme-next-the-sea (Howarth, 1920, p. 221) or it plays an unimportant role on the outermost fringe of Juncetum (Tansley, 1911). The work of Newman and Walworth on the South Lincolnshire coast, indicates the presence of *Festuca rubra* amongst the marsh halophytes and even forming a special *Festuca-Salicornia* Zone (1919, p. 208).

Festuca rubra does not actually occur on the Sydney saltmarshes, but is generally found on the higher slopes immediately outside the limits of *Juncetum*. It occurs with non-halophytes such as species of *Plantago*, *Trifolium*, *Brisa*, and others in a region higher than Warming's "higher littoral meadow" (1909, p. 231). With increasing age and with elevation of surface level, it is possible that *Festuca* and other grasses may yet play an important role on the Sydney saltmarshes.

The depressions known as pans, which are such a constant feature of the British marshes (Carey and Oliver, 1918; Yapp, etc., 1917) are not found near Sydney. This may doubtless be accounted for in the comparative youth of the tidal flats near Sydney. There are shallow bare depressions however, in which water remains for some time after the tides have receded. These more closely resemble the salt marsh pools described by Harshberger (1916) for the New Jersey coast.

SUMMARY.

1. Physiographic features of the coast in the neighbourhood of Sydney are briefly dealt with in relation to the formation of sheltered tidal flats.
2. The two plant formations of these tidal flats are discussed and an account of their developmental phases given.

TABLE COMPARING VEGETATION OF TIDAL MARSHES.

ENGLAND. Types of British Vegetation. Tansley (1911).	WALES. Dovey Estuary. Yapp (1917).	U.S.A. Bay of Fundy, New Brunswick. Ganong (1903).	U.S.A. Cold Spring Harbour, Long Island. Johnson & York (1915).	AUSTRALIA. Sydney, N.S.W. Collins (1921).
1. SALICORNIETUM. *Salicornia Europaea.* *Glyceria maritima.* *Triglochin maritimum.* *Aster Trifolium.* 2. GENERAL SALTMARSH ASSOCIATION. *Spergularia marginata.* *S. salina.* *Aster Tripolium.* *Artemisia maritima.* *Statice limonium.* *Armeria maritima.* *Plantago maritima.* *Atriplex portulacoides.* *Salicornia Europaea.* *S. radicans.* *Suaeda maritima.* *Triglochin maritimum.* *Glyceria maritima.* 3. GLYCERIETUM. *Glyceria maritima.* *Statice Limonium.* *Armeria maritima.* *Suaeda maritima.* 4. JUNCETUM. *Juncus maritimus.* *Oenanthe Lachenalii.* *Glaux maritima.* *Plantago maritima.* *P. coronopus.* *Agropyrum pungens.* *Agrostis palustris.* *Festuca rubra.*	1. SALICORNIETUM. 2. GLYCERIETUM. *Glyceria maritima.* *Salicornia Europaea.* 3. ARMERIETUM. *Armeria maritima.* *Glyceria maritima.* *Festuca rubra.* *Lepturus filiformis.* *Glaux maritima.* *Triglochin maritimum.* 4. FESTUCETUM. *Festuca rubra.* a. Lower. *Armeria maritima.* *Juncus Gerardi.* *Lepturus filiformis.* *Glaux maritima.* *Plantago coronopus.* *Triglochin maritimum.* *Aster Tripolium.* b. Upper. *Agrostis alba coarctata.* *Plantago coronopus.* *Juncus Gerardi.* *Armeria maritima.* *Triglochin maritimum.* 5. JUNCETUM. *Juncus Gerardi.* *Festuca rubra.* *Agrostis alba coarctata.* *Cochlearia officinalis.* *Spergularia marginata.* *Aster Tripolium.* *Triglochin maritimum.*	1. SPARTINETUM. *Spartina glabra.* 2. SALICORNIETUM. *Salicornia herbacea.* *Suaeda maritima.* *Spergularia borealis.* *Atriplex hastatum (patulum).* 3. STATICETUM. *Statice limonium.* *Plantago maritima.* *Spartina patens.* *Puccinellia maritima.* *Festuca ovina.* *Juncus Gerardi.* *Triglochin maritimum.* *Hordeum jubatum.* *Glaux maritima.*	Mid-littoral Belt. 1. SPARTINETUM. *Spartina glabra.* *Lilaeopsis lineata.* Upper Littoral Belt. 2. MIXED SALTMARSH. *Spartina patens.* *Suaeda maritima.* *Salicornia Europaea.* *Juncus Gerardi.* *Scirpus Americanus.* *S. robustus.* *Distichlis spicata.* *Salicornia ambigua.* *Atriplex patula.* *Limonium Carolinianum* *Plantago decipiens.* *Scirpus nanus.* *Triglochin maritimum.* *(*Atriplex arenaria*). *(*Iris versicolor*). *(*Samolus floribundus*). *(*Spergularia marina*). *rare.	A. Mangrove Formation. *Avicennia officinalis.* *Aegiceras majus.* B. Saltmarsh - Formation. 1. SALICORNIETUM. i. Salicornia-Suaeda Associes. *Salicornia australis.* *Suaeda australis.* ii. Salicornia-spergularia Associes. *Salicornia australis.* *Spergularia rubra.* *Samolus repens.* *Suaeda australis.* *Mesembryanthemum tegens.* *Tetragonia expansa.* *Atriplex hastata (patula).* **Wilsonia Backhousii.* iii. Sporobolus-Cynodon Associes. *Sporobolus virginicus.* *Cynodon dactylon.* *Zoysia pungens.* Other perennial halophytes. 2. JUNCETUM. *Juncus maritimus.* *Casuarina glauca.*

3. The first and outermost is mangrove formation characterised by two species, *Avicennia officinalis* and *Aegiceras majus*.
4. The second, inner formation is saltmarsh, in which two associations are recognised, (*a*) *Salicornietum*, (*b*) *Juncetum*.
5. Developmental groups or associes of Salicornietum are often found in zoned arrangement according to slight differences in level.
6. With accretion and attainment of uniform surface level, these associes mingle to find ultimate expression in mature *Salicornia* association.
7. Special conditions at Cabbage Tree Creek, Port Hacking, are described. Here, drift sand has been raising the level of the marsh for some years and has brought about the imposing of one formation upon another. At the present day the marginal association of the saltmarsh—*Juncetum*—is invading Salicornietum, which consequently shows signs of arrested development.
8. The occurrence of a dwarf-form of *Avicennia officinalis* is recorded for Cabbage Tree Creek, Port Hacking.
9. In a general discussion and table the vegetation of the tidal flats near Sydney is compared with those of Great Britain and other countries.

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EXPLANATION OF PLATES XXVI.-XXXII.

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Plate xxvi.

Photo 1. Mangrove formation *(Avicennia)* at high tide, Middle Harbour, Port Jackson.

„ 3. Close view of *Avicennia officinalis* showing pneumatophores. Middle Harbour, Port Jackson.

Plate xxvii.

Photo 2. Interior of Mangrove formation at Port Hacking, showing distorted branches of *Avicennia officinalis* and pneumatophores.

„ 4. Cabbage Tree Creek, Port Hacking showing extensive development of *Aegiceras majus* on inner limits of Mangrove formation. Ground vegetation of *Salicornia* and *Samolus* beneath mangrove.

Plate xxviii.

Photo 5. *Aegiceras majus* Port Hacking. Pneumatophores have arisen from a neighbouring *Avicennia.*

„ 6. *Aegiceras majus* with cluster of viviparous fruits.

„ 7. Junction of *Sporobolus-Cynodon* Associes and *Salicornia-Samolus* Associes within Salicornietum at Middle Harbour, Port Jackson. Note: *Samolus* replaces *Spergularia* in this region as co-dominant with *Salicornia.*

Plate xxix.

Photo 8. *Avicennia officinalis* (tree) and low bushes of *Aegiceras majus* near mouth of Cabbage Tree Creek, Port Hacking. Note horizontal roots bearing pneumatophores uncovered by action of tides. Outskirts of encroaching sand are seen to the left.

„ 9. *Avicennia officinalis* and *Aegiceras majus* being buried in drift sand. Dwarf *Avicennia* in right middle distance. Cabbage Tree Creek, Port Hacking.

Plate xxx.

Photo 11. Group of old trees of *Avicennia officinalis* near mouth of Cabbage Tree Creek, Port Hacking. Note pneumatophores and dwarf *Avicennia* beneath trees. Foreground occupied by sward of *Samolus repens* with a few clumps of *Juncus maritimus* Right foreground shows bush of *Aegiceras majus*.

Photo 12. Dwarf-growth of *Avicennia officinalis*. *Samolus repens* in foreground.

Plate xxxi.

Photo 13. Juncetum *(Juncus maritimus)* with group of young *Casuarina glauca* advancing upon Salicornietum at Cabbage Tree Creek, Port Hacking.

„ 14. Band of *Juncus maritimus* passing through Salicornietum to inner limits of mangrove.

Avicennia officinalis on right foreground and regular line of *Aegiceras majus* in middle distance.

Plate xxxii.

Photo 15. Juncetum with old decaying trunks of *Casuarina glauca* at Cabbage Tree Creek. Mangrove "inlier" in right background.

„ 10. Mangrove "inlier" *Avicennia* at Cabbage Tree Creek, Port Hacking. Ground vegetation of *Salicornia*, *Samolus* and *Sporobolus*.